Abstract

China has not only both onshore and offshore money (capital) markets but also both onshore and offshore currency markets. The differences between onshore and offshore RMB markets would cause many questions that are worth probing into. This paper implements a simple model to explain Chinese onshore and offshore financial markets and fill the gap of the term spread differential of money market and CIP violation of currency market spillover effects. The empirical test uses a new flexible econometric method - Bayesian local projections that can sensibly reduce the impact of compounded biases over the horizons and effectively deal with model misspecifications. The results are three-fold: First, one market shock can transmit to the other market through capital flows. The shocks from the forward currency market have a significant impact on the spot money market through capital flows. The effects on both markets would die away in a week after initial shocks, but the effect on capital flows is less persistent. Second, cheaper net cost of issuance in offshore induces more issuance flow in offshore and less issuance in onshore. Third, a massive amount of debt issuance may decrease the absolute value of the net deviation.

1 Introduction

The influence of RMB has been growing in recent years as the Chinese economy expanding after the financial crisis. According to the latest Bank of International Settlements Triennial Central Bank Survey on the foreign exchange market, RMB now ranks as the world’s sixth most traded currency. For several years Chinese authorities have argued for the desirability
of an alternative to the U.S. dollar as the key reserve currency so that they are now moving in the direction of reducing their dependence on the U.S. dollar by internationalizing RMB. The internationalization of RMB may gain benefits such as decreasing exchange risks of international trade and investment, thereby reducing transaction costs, the People’s Bank of China (PBoC), the central bank of China, founded offshore markets as a trial of RMB internationalization and a harbinger for domestic financial system liberalization in Hong Kong since 2010 which is known as the CNH market. Unlike the onshore foreign exchange market (CNY market), the offshore market (CNH market) is a relatively efficient market without restrictions in the onshore market.

This study is motivated to examine China’s consistent onshore-offshore CIP deviations by particular shocks. Liao [2016] decomposed the CIP deviations to money market deviations and currency market deviations. In his model, the firm could choose issue bonds in one market, either in the Euro market or the U.S. market, to minimize the borrowing cost. Furthermore, the money market shocks or currency market shocks would affect the decision of this firm. However, this paper adds the financing time cost of banks to fit the scenario of China onshore and offshore markets, which means banks would issue bonds in both the onshore and offshore markets. Following Liao [2016], this paper modifies his model to explain Chinese onshore and offshore financial markets and fill the gap of the term spread differential and CIP violation spillover effects. This static model includes three agents - a bank, investors in the money market, and traders in the currency forward market. Onshore and offshore specialized investors actively allocate assets in the money market, and forward arbitrage trader makes a profit through CIP deviations in the currency forward market. Further, a representative bank connects these two markets by engaging FX hedge debt allocation. When the onshore relative to offshore credit spread (term spread) is high, the bank allocates a greater share of RMB debt in the offshore market. An increase in the offshore CNH, however, generates CNH exposure, which the bank hedges through currency forwards. Alternatively, when CIP deviations (transaction cost) are large, the bank chooses to minimize borrowing costs (credit spread cost and transaction cost) and financing time cost simultaneously and then decides on the optimal share. The two violations of money and currency markets are the primary consideration of the representative bank for debt issuance.

This paper estimates two types of exogenous shocks that affect this system. First, bond demand shocks in the money market are caused by monetary policy, investor preference, and money market regulatory. Second, non-issuance-related use of currency forward contracts
shocks in the currency forward market includes central bank policy - FX intervention, trader expectation driven hedging and arbitraging demands, and currency market regulatory - capital control. Other literature on China’s foreign exchange rate has not covered the capital control policy using a daily index to measure the level effect of the deviation from covered interest parity. This paper aims to fill that critical void. These two shocks have spillover effects from the RMB spot market (money market) to the forward market (currency market), and the other way around.

In the money market, this paper uses offshore-onshore term spread deviations \( c = (r_{off}^a - r_{off}^{o/n}) - (r_{on}^a - r_{on}^{o/n}) \)
\( 1 \) to measure money market gaps. Figure 1 shows the RMB and USD exchange rate in onshore and offshore currency markets. There were persistent discrepancies in the pricing of currency exchange forward between \( F_{on} \) and \( F_{off} \) before 8/10/2015. After that, but before 7/5/2017, spot exchange rates \( S_{on} \) and \( S_{off} \) existed significant gaps during some periods. Currently, the converging power shows in both onshore and offshore, and spot and forward exchange rate. In the currency market, this paper calculates onshore-offshore CIP deviations \( b = r_{on}^{o/n} + s - f - r_{off}^{o/n} \) to estimate currency market gaps, where the spot exchange rate between onshore CNY and offshore CNH is \( 1 + s \equiv \frac{S_{on}}{S_{off}} \), and the forward exchange rate is \( 1 + f \equiv \frac{F_{on}}{F_{off}} \). The money market offshore-onshore term spread deviations and currency market onshore-offshore CIP deviations are displayed in Figure 2.

\[ c = (r_{off}^a - r_{off}^{o/n}) - (r_{on}^a - r_{on}^{o/n}) \]

\( 1 \) If \( c = (r_{off}^a - r_{off}^{o/n}) - (r_{on}^a - r_{on}^{o/n}) \), this equation can be interpreted to overtime offshore-onshore credit spread deviation.
Figure 2: on 1/12/2016 c=-57.9054, b=-61.04023; on 1/5/2017 c=-52.4599, b=-54.8629; on 6/1/2017 c=-21.1185, b=-21.14572

Figure 3: offshore-relative-to-onshore total cost

Figure 3 reveals the consideration of representative bank that faces the total funding cost of offshore relative to onshore. Before 8/10/2015, offshore funding was better than onshore for this representative bank. Between 8/11/2015 and 7/5/2017, this representative bank
would prefer to issue onshore bond rather than borrow offshore money, due to positive gaps 
$c − b > 0$. Nowadays, the gaps are more random deviation. This paper is structured as 
follows: literature review in part two; modeling bank’s strategy in onshore-offshore RMB 
money and currency markets in part three; empirical data analysis and Bayesian local pro-
jections in part four; conclusion in the last part.

2 Literature Review

The expanding Chinese currency forward markets have revitalized research interest in the 
capital control effect on onshore-offshore carry trades and the significance of CIP deviation. 
Existing studies on onshore and offshore foreign exchange markets tend to focus on causality 
between the two, e.g., Burdekin and Tao [2013]. They used the Granger causality test on the 
onshore-offshore spread. By cointegration method Ding et al. [2014] found that price discov-
ery is absent between the onshore and offshore spot markets; however, the price discovery 
exists between onshore spot and offshore nondeliverable forward (NDF) rates. Owyong et al. 
[2015] implemented bidirectional linear and nonlinear causality on several sets of spot and 
forward prices. Their results suggested stronger causality running from the spot onshore rate 
to the spot offshore rate than vice versa, which implies that foreign impulses have influenced 
the domestic market. Despite trading and capital restrictions, Peng et al. [2007] found that 
sentiment can spillover between the onshore and offshore markets and that over time, the 
relative contribution of price leadership has shifted between the onshore and offshore centers.

GARCH model is another quantitative method used in the research. Maziad and Kang 
[2012] employed a bivariate GARCH model to understand the inter-linkages between onshore 
and offshore markets and found that, while developments in the onshore spot market exert 
an influence on the offshore spot market, offshore forward rates have a predictive impact 
on onshore forward rates. Funke et al. [2015] implemented an extended GARCH model to 
measure the policy effect on both the conditional level and volatility of CNH-CNY spread. 
Cheung and Rime [2014] used a specialized microstructure dataset to study the CNH ex-
change rate dynamics and its links with onshore exchange rates (CNY). They concluded 
that the offshore CNH exchange rate has an increasing impact on the onshore rate CNY 
and significant predictive power for the official RMB central parity rate. Craig et al. [2013] 
attributed the CNH-CNY price differential to onshore investor risk sentiment and capital 
account liberalization. They applied an asymmetric self-excited threshold auto-regression 
(SETAR) model to the daily CNY-CNHS price differential from September 2010 to January
2013 and found limited integration between CNY and CNH market. These works of literature conclude the existence of CIP deviation on both onshore and offshore RMB forward markets.

In addition to these works of literature on the research for the correlation of RMB FX markets, two kinds of literature focusing on the deviation of CIP through decomposition to investigate the market segmentation. The first strand is that the liquidity of the global market affects the funding of arbitrage and then induces the deviation. Ivashina et al. [2015] concluded that banks can borrow in euros and swap into dollars to make up for the dollar shortfall, but this may lead to violations of covered interest parity when there is limited capital to take the other side of the swap trade. Bräuning and Ivashina [2016] further explored the role of monetary policy in affecting global bank’s funding sources and the use of FX hedges. Iida et al. [2016] provided theoretical evidence to show that monetary policy divergence between the Federal Reserve and other central banks widens CIP deviations and that regulatory reforms such as stricter leverage ratios raise the sensitivity of CIP deviations to monetary policy divergence by increasing the marginal cost of global banks’ USD funding. Cetorelli and Goldberg [2012] reported that global banks actively manage liquidity using internal cross-border financing in response to domestic shocks. The other strand is the banking sector issues. Sushko et al. [2017] and Du et al. [2016] focused on the banking sector and the ability of banks to take on leverage. The key message is that the value of the dollar plays the role of barometer of risk-taking capacity in global capital markets. When the dollar strengthens, CIP deviations widen. Du et al. [2016] formally established CIP arbitrage opportunities that cannot be explained away by credit risk or transaction costs, and present evidence that bank balance sheet costs and asymmetric monetary policy shocks are the primary drivers of CIP deviations. Borio et al. [2016] constructed empirical proxies for net hedging demand of different national banking systems and show that they are consistent with the cross-sectional variations in CIP deviations. Liao [2016] documented economically significant and persistent discrepancies in the pricing of credit risk between corporate bonds denominated in different currencies. This violation of the Law-of-One-Price (LOOP) in credit risk is closely aligned with violations of covered interest rate parity in the time series and the cross-section of currencies. One recent work, Ho et al. [2018] applied a Mixture of Distribution Hypothesis and Veronesi [1999]’s theory to the exchange rate market and examined the respond of exchange rate volatility to the market information.
3 A Model of Onshore-Offshore Money Market and Currency Market Deviations

This static model includes three agents (bank, investors in the money market, and traders in the forward currency market) and two exogenous shocks. Bank issues bonds in onshore and offshore money markets and uses currency forward to hedge offshore bond issuance. The representative bank minimizes borrowing cost and financing time cost to choose the share of onshore issuance. Investors in onshore and offshore money markets buy bonds. Investors would maximize investment return to choose the investment amount. Traders in the forward currency market do carry trade with forward contracts. Traders would also maximize investment return to choose the investment amount. $\varepsilon_c$ is offshore-relative-to-onshore bond demand shock in the money market. Furthermore, $\varepsilon_b$ is other non-issuance-related use of currency forward contracts shock in the currency forward market.

3.1 Bank Decision

A bank chooses a fixed amount of RMB debt $D$ that needs to be borrowed and faces two costs for issuing onshore-relative-to-offshore bonds: term spread differential onshore and offshore RMB $-c = (r_{on}^a - r_{on}^{o/n}) - (r_{off}^a - r_{off}^{o/n})$, and transaction cost (CID) across the onshore and offshore boundary $b = r_{on}^{o/n} + s - f - r_{off}^{o/n}$. For term spread differential, one is the onshore CNY bond yield $r_{on}^a$. The other is offshore CNH bond yield $r_{off}^a$ in offshore financial centers like Hong Kong, Singapore, or London. Then, the bank observes a credit spread differential between onshore and offshore RMB bond yields to adjust the risk-free interest rate difference denoted as $-c = (r_{on}^a - r_{off}^a) - (r_{on}^{o/n} - r_{off}^{o/n})$, which also measures the interest rate term spread differential. If the money market does not have an arbitrage opportunity, the credit/term spread $c = 0$ fails most of the time due to market segmentation. For transaction costs (CID), furthermore, if the bank borrows money from the offshore market, it has an add-on cost $b$ across the onshore and offshore boundary. This paper uses the U.S. currency as a bridge to measure this transaction cost $b$. If CIP holds between CNY/CNH and USD, it means $(1 + r_{on}^{o/n}) = \frac{F_{on}}{S_{on}} (1 + r_{us})$ and $(1 + r_{off}^{o/n}) = \frac{F_{off}}{S_{off}} (1 + r_{us})$, where $S_{on}$ or $S_{off}$ is spot exchange rate and $F_{on}$ or $F_{off}$ is forward exchange rate both expressed in onshore CNY or offshore CNH per USD. Then the spot exchange rate between onshore CNY and offshore CNH is $1 + s \equiv \frac{S_{on}}{S_{off}}$, and the forward exchange rate is $1 + f \equiv \frac{F_{on}}{F_{off}}$. If currency forward market onshore-offshore RMB CIP holds, the transaction cost $b = r_{on}^{o/n} + s - f - r_{off}^{o/n} = 0$, which means there would be no carry trade opportunity. What’s more, if the onshore issuance
share $\mu$ deviates the threshold share $\theta$, it would cause financing time cost $\omega$. Therefore, the bank chooses onshore issuance share $\mu$ to minimize onshore-relative-to-offshore bond cost and financing time cost.

$$\min_{\mu} \left( -c \text{ interest rate term spread diff} + b \text{ transaction cost} \right) \mu D + \frac{\omega}{2} (\theta - \mu)^2 \text{ financing time cost} \quad (1)$$

which has the solution $c - b = \frac{\omega(\mu - \theta)}{D}$.

First, if the net deviation is more negative $c - b \downarrow$, then the bank chooses a lower onshore issuance share $\mu \downarrow$ because onshore issuance is costly; otherwise, it chooses $\mu \uparrow$. Second, if the total amount of debt $D$ is large enough, then $c - b$ is driven to zero as a result of arbitrage. According to these two derivations, two deviations $c$ and $b$ are aligned when a large amount of cross-market capital flows exist.

### 3.2 Money Markets

There exist three main market participants: active offshore investors, active onshore investors, and the representative bank from above that has access to both onshore and offshore money markets. Offshore active investors focus on the investment of the offshore money market, and onshore investors invest in the onshore money market exclusively. Investors borrow at the risk-free interest rate $r_{o/n}^i$ and invest at the money market with a guaranteed yield to maturity of $r_i^a$, where $i$ represents either onshore or offshore. The two bonds have an identical default probability $\pi$, loss-given-default $L$. The payoff of bonds has a variance of $V$, which is treated as an exogenous constant in the model for tractability. Onshore and offshore investors have a mean-variance preference with identical risk tolerance $\tau$ and choose investment amount $X_i$ to solve the following

$$\max_{X_i} X_i \left[ \left( (1 - \pi) r_i^a - \pi L - r_{o/n}^i \right) - \frac{1}{2\tau} X_i^2 V \right] \quad (2)$$

which has the solution $X_i = \frac{\tau}{V} \left( (1 - \pi) r_i^a - \pi L - r_{o/n}^i \right)$ for $i = \text{onshore or offshore}$.

**Money market clearing conditions**
There are exogenous offshore-relative-to-onshore bond demand $\varepsilon_c$, perhaps representing demand shocks that emerge from monetary policy, investor preference, and money market regulatory. Combining the demand with bank supply showed earlier, the market clearing conditions for onshore and offshore money markets are

$$X_{on} = \mu D \quad (3)$$

$$X_{off} + \varepsilon_c = (1 - \mu)D \quad (4)$$

Combining the investor demands with the market clearing conditions and applying first-order Taylor approximation for $\pi$ around 0, money market section can derive the CNH-CNY interest rate term spread differential as:

$$c = \frac{V_T}{\tau} \left( \frac{(1 - 2\mu)D}{\text{relative bond supply}} - \frac{\varepsilon_c}{\text{exog. bond demand}} \right) \quad (5)$$

The interest rate term spread differential $c$ represents arbitrage opportunity in the money market since the default probability and loss given default are identical for the two bonds. Equation (5) induces that $c$ is determined by the net bond supply between offshore and onshore money markets multiplied by the elasticity.

### 3.3 Currency Forward Market

This section describes the dynamics of the currency forward market. The insight is similar to that of money market violation, but intermediary collateral and capital constraints limit deviation in CIP. There are two main participants in this market: currency forward traders and issuers.

Currency forward traders choose the amount of capital to allocate to either CIP deviation, denote as $b$, or other investment opportunity with profit of $f(I)$, where $I$ is the amount of investment. The arbitrage has to set aside a haircut $H$ when it enters the forward transaction to trade the CIP violation. Following Garleanu and Pedersen [2011], the amount of haircut is assumed to be proportional to the size $s$ of the forward position, $H = \gamma s$. So,
the capital allocated towards alternative investment is \( I = W - \gamma |s| \). Forward traders have total wealth \( W \) and maximize the following

\[
\max_s \quad bs + f (W - \gamma |s|)
\]

which generates the direct result that the expected benefit from carrying an extra unit of CIP arbitrage is equal to the marginal profitability of the alternative investment, \( b = \text{sign}[s] \gamma f'(W - \gamma |s|) \). In a simple case, assume the alternative investment activity is quadratic, \( f(I) = \phi_0 I - \frac{1}{2} \phi I^2 \), \( b = \text{sign}[s] \gamma (\phi_0 - \phi W + \gamma \phi |s|) \).

The model makes a further simplifying assumption that CIP deviation \( b \) is linearly related to the net demand for forwards, equivalently to stating \( W = \frac{\phi_0}{\phi} \), which means that arbitrageur has just enough wealth \( W \) to take advantage of all positive-NPV investment opportunities in the alternative project \( f(I) \). This assumption helps to reduce the constant intercept term in the equation for \( b \), and derives that CIP deviation is proportional to forward trader position, \( b = \phi \gamma^2 s \). The model normalizes \( \phi = 1 \).

**Currency forward market clearing conditions**

The representative bank from above relies on the forward currency market to hedge its offshore debt issuance - amount \( (1 - \mu)D \) CNH. Also, there are exogenous shocks to CIP basis \( \varepsilon_b \) that represent other non-issuance-related use of currency forward contracts. Market clearing condition of the currency forward market shows that the equilibrium level of CIP deviation satisfies

\[
\begin{align*}
\frac{b}{\text{CIP basis}} &= -\gamma^2 \frac{(1 - \mu)D + \varepsilon_b}{\text{haircut on collateral net hedging demand}} \\
\end{align*}
\]

Equation (7) indicates that CIP deviation \( b \) is proportional to net hedging demand multiplied by the elasticity, which is determined by the collateral margin. Higher haircut \( \gamma \) strengthened the shock of hedging demand, but without net hedging demand, \( b \) does not deviate from zero.
3.4 Summary of Equilibrium Conditions

The three equilibrium conditions are summarized as follows (endogenous variables: $c$, $b$, $\mu$; exogenous shocks: $\varepsilon_c$, $\varepsilon_b$):

(1) Term spread differential (offshore-onshore):

$$c = \frac{V}{\tau} (1 - 2\mu) (D - \varepsilon_c)$$

(8)

(2) CIP basis:

$$b = -\frac{\gamma^2}{2} (1 - \mu) (D + \varepsilon_b)$$

(9)

(3) Bank choice of bond issuance ratio:

$$\mu = \frac{(c - b)D}{\omega} + \theta$$

\begin{align*}
\text{if } c - b \uparrow, & \text{ cheaper to issue in onshore} \\
\text{if } c - b \downarrow, & \text{ cheaper to issue in offshore}
\end{align*}

(10)

With these equilibrium conditions, this model can analyze the transmission of $\varepsilon_c$ and $\varepsilon_b$ shocks from one market to the other.

**Proposition 1.** *(Spillover of deviations)* If $\varepsilon_c \downarrow$, then $c \uparrow \Rightarrow \mu \uparrow \Rightarrow b \uparrow$. If $\varepsilon_b \downarrow$, then $b \uparrow \Rightarrow \mu \downarrow \Rightarrow c \uparrow$. One market shock can transmit to the other market through capital flows. Interest rate term spread differential $c$ and CIP deviation $b$ reflect in the same direction to either exogenous bond demand shocks $\varepsilon_c$ or exogenous currency forward demand shocks $\varepsilon_b$. RMB bond issuance $\mu$ reflects oppositely to the two shocks.

**Proposition 2.** *(Issuance flow and net deviation)* $(c - b) \downarrow \Rightarrow \mu \downarrow$. Cheaper net cost of issuance in offshore induces more issuance flow in offshore and less issuance in onshore.

**Proposition 3.** *(Arbitrage capital and aligned deviations)* Since $\frac{\partial|c-b|}{\partial D} < 0$ so that $\lim_{D \to \infty} c - b = 0$. A large amount of debt issuance may decrease the absolute value of the net deviation. With infinity capital flows, the two deviations become identical.
4 Empirical Results

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Source: Bloomberg, FRED, Wind and China Bureau of Statistics

4.1 Dataset

This section uses empirical data to generate endogenous variables (c, b, µ) and exogenous shocks (ε<sub>c</sub>, ε<sub>b</sub>) in the model. The period is from 11/3/2014 to 9/5/2018, daily data. **Interest rate term spread differential** c = (r<sub>a</sub><sup>off</sup> - r<sub>o</sub><sup>n</sup>) - (r<sub>a</sub><sup>on</sup> - r<sub>o</sub><sup>n</sup>) is calculated by Shanghai interbank offered rate (1 year and overnight) and Hong Kong interbank offered RMB rate (1 year and overnight). This paper assumes the overnight rate is a risk-free rate. **Transaction cost CIP deviation** b = r<sub>o</sub><sup>n</sup> + S<sub>on</sub> - F<sub>on</sub> - r<sub>off</sub> is estimated by onshore and offshore risk-free rates, and CNY/CNH spot and forward exchange rates which use RMB/USD as a connection. **Capital flow onshore share** µ = \( \frac{volume_{on}}{volume_{on} + volume_{off}} \) or \( \mu = \frac{amount_{on}}{amount_{on} + amount_{off}} \) is measured by 5-year bond ETFs traded in Shanghai and Hong Kong (same underlying assets) volume/amount. The two methods are highly correlated (ρ = 0.9997); the paper would use volume calculated µ to measure capital flow. **Exogenous bond demand shocks** ε<sub>c</sub> in the money market are caused by monetary policy, investor preference, and money market regulatory. **Exogenous currency forward demand shocks** ε<sub>b</sub> (non-issuance-related use of currency forward contracts) in the forward currency market are influenced by central bank policy - FX intervention, trader expectation driven hedging and arbitraging demands, and
4.2 Source of Shocks

4.2.1 Money Market Shocks

Monetary policy People’s Bank of China sets a reserve ratio to influence the money supply. Commercial banks are required to hold reserves against their total reservable liabilities, rather than lend out or invest. Any changes in reserve ratio would cause money market shocks, which could affect bond demand because of the different responses in onshore and offshore money markets. For instance, the central bank increases the required reserve ratio (RRR) to reduce the money supply in the economy. Therefore, the risk-free rate rises and financial capital would flow from risky assets to safe assets. The older bonds with a relatively low premium (original yield minus new risk-free rate) would become less attractive. Demand for the bonds would decline in both onshore and offshore money markets because the low premium would not be worth taking on the risk. Due to different responses of investors, the offshore demand would reduce more than onshore, which is a negative shock on $\varepsilon_c$. Finally, the yield of bonds would rise until supply and demand reached a new equilibrium in each market, then interest rate term spread differential $c$ rises. This paper uses the changed RRRs as shocks in the money market.

Investor preference The stock market is a crucial part of the financial market to investors. CSI 300 is a blue chip index for top 300 stocks in Mainland China stock exchanges to measure the performance of the onshore stock market. What’s more, HSI is a blue chip index for top 50 stocks in Hong Kong stock exchanges to measure the performance of the offshore stock market. The detrended indices of daily log-form closing price are the cyclical components as shocks. The index shocks of both onshore and offshore markets are a positive correlation ($\rho = 0.44$). A positive shock of offshore-relative-to-onshore stock market indices would cause capital inflow from the bond market to the stock market because of investor preference (seeking high return and low risk assets) and substitution effect. Therefore, the offshore-relative-to-onshore bond demand shock is negative $\varepsilon_c$. A new equilibrium of the bond market has a higher yield $c$, which is consistent with the prediction of the model.

Money market regulatory People’s Bank of China could use a repurchase agreement (REPO) or a reverse repurchase agreement (Reverse REPO), classified as a money market instrument, to decrease or increase short-term liquidity as one of open market operations.
A positive shock of the reverse repurchase agreement (R-REPO) means the central bank increases short-term liquidity. In other words, the central bank purchases bonds now and agrees to sell them in the future. Then, the central bank pushes the traditional government bond investors in search of high-yielding bonds. Therefore, onshore bond demand rises (offshore-relative-to-onshore bond demand drops), which has a negative impact on $\varepsilon_c$. The increasing short-term liquidity would trigger that onshore yield falls, so interest rate term spread differential $c$ rises.

4.2.2 Currency Market Shocks

Central bank policy People’s Bank of China can implement foreign exchange intervention through changing currency liquidity. The bid-ask spread is a reflection of the demand and supply for the asset. Due to the difference in liquidity of each asset, the size of the bid-ask spread from one asset to another varies. Here, this paper uses onshore and offshore RMB/USD exchange rate bid-ask spreads to measure the onshore-offshore CNY/CNH liquidity.\(^2\) The liquid asset has a small bid-ask spread in the currency market. A positive shock on CNY/CNH liquidity means that the spot exchange rate CNY/CNH currency market has less liquidity. From a currency market trader’s perspective, liquidity is usually experienced in terms of the volatility of price movements. A liquid asset will tend to see prices move very gradually and in small increments. An illiquid asset will tend to see prices move abruptly and in large price increments. When traders face a risky currency market, non-issuance-related use of currency forward contracts $\varepsilon_b$ increases. Thus, the offshore strategy becomes costly, then the onshore-relative-to-offshore transaction cost (CIP basis) $b$ would fall.

Trader expectation In China’s onshore spot foreign exchange market, RMB is allowed to rise or fall by 2 percent from the central parity rate each trading day, but the daily trading band does not impose on the offshore foreign exchange market. Therefore, the risk could be from a sizeable uncertain movement of CNH/USD in the offshore currency market. The gap of CNH/USD and central parity rate is divided by the gap of CNY/USD and central parity rate to measure offshore-relative-to-onshore exchange rate volatility. If the result is less than the threshold -2, the offshore exchange rate is more volatile than onshore one in the

\(^2\)Because the spot exchange rate between onshore CNY and offshore CNH is $1 + s = \frac{S_{on}}{S_{off}}$, the CNY/CNH bid price is $1 + b = \frac{S_{b\text{on}}}{S_{b\text{off}}}$ and the CNY/CNH ask price is $1 + a = \frac{S_{a\text{on}}}{S_{a\text{off}}}$. However, the onshore-offshore liquidity gap used in this paper is the difference between onshore CNY/USD bid-ask spreads ($S_{a\text{on}} - S_{b\text{on}}$) and offshore CNH/USD bid-ask spreads ($S_{a\text{off}} - S_{b\text{off}}$).
opposite direction.\(^3\) When traders see a more volatile offshore market and opposite deviation from the central parity rate against the onshore market, they will use currency forward contracts \(\varepsilon_b\) to hedge risk or pursue arbitrage opportunity. As a result, the excess demands of currency forward contracts increase the cost of offshore strategy, and CIP basis \(b\) would fall.

**Currency market regulatory** Capital control represents any methods taken by the People’s Bank of China to limit the capital inflow and outflow to and from the domestic economy. Capital controls can affect many assets, such as bonds, stocks, and foreign exchange trades. Because the de jure indices like IMF’s AREAER and Chinn-Ito with annual frequency would not reflect an effectiveness after a policy changing, this paper calculates a daily capital control index which follows the basic index construction method according to Schindler [2009] with 7 AREAER asset subcategories including portfolio equity investment, bond investment, money market investment, collective investment, derivative investment, commercial credits and real estate investment. The capital control index is between 1 and 0 to measure the degree from full capital controls to free capital flows. A positive shock of changed daily capital control index would cause more controls on free capital movement. The capital control could lower risks associated with the volatility of capital flows in the onshore currency market, but this regulatory would expand the gap between offshore and onshore currency markets. Consequently, the demands of currency forward contracts \(\varepsilon_b\) increase, and onshore-relative-to-offshore CIP basis \(b\) decreases.

<table>
<thead>
<tr>
<th></th>
<th>Correlation ∆RRR ↑</th>
<th>HSI-CSI ↑</th>
<th>R-REPO ↑</th>
<th>BAS ↑</th>
<th>DCPR ↑</th>
<th>∆CCI ↑</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\varepsilon_c) ↑</td>
<td>↓ 0.0287</td>
<td>0.1276</td>
<td>0.0448</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\varepsilon_b) ↓</td>
<td>↑ -0.0678</td>
<td>-0.0473</td>
<td>-0.0320</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^3\)If \(\frac{DCPR_{off}}{DCPR_{on}} < -2\), \(\varepsilon_b = 1 + \frac{DCPR_{on}}{DCPR_{off}}\); otherwise, \(\varepsilon_b = 0\). Therefore, \(\varepsilon_b\) is between 0 (less risky) and 1 (more risky).
4.3 Proposition 1 Test

4.3.1 Bayesian Local Projection Method

Miranda-Agrippino and Ricco [2017] provided a flexible econometric method - Bayesian local projections robust to misspecifications that bridges between vector autoregressions (VARs) and local projections (LPs). The VARs produce IRFs by iterating up to the relevant horizon the coefficients of a one-step-ahead model. However, because of a small-size information set, underestimated lag order, and non-linearities, misspecified VARs can fail to capture all of the dynamic interactions. $y_{t+1} = C + B_1 y_t + . . . + B_p y_{t-p+1} + \epsilon_{t+1}$ The LPs, Jordà [2005], estimate the IRFs from the coefficients of direct projections of variables onto their lags at the relevant horizon. However, due to the moving average structure of the residuals, and the risk of over parametrization, LPs are likely to be less efficient, and hence subject to volatile and imprecise estimates. $y_{t+h} = C + B_1 y_t + . . . + B_p y_{t-p+1} + \epsilon_{t+h}$ Therefore, choosing between iterated and direct methods involves a sharp trade-off between bias and estimation variance: the VAR produces more efficient parameter estimates than the LP, but it is prone to bias if the one-step-ahead model is misspecified.

Miranda-Agrippino and Ricco [2017] proposed a regularization for LP-based IRFs, which builds on the prior that a VAR can provide, in first approximation, a decent description of the behavior of most variables. As the horizon grows, however, BLPs are allowed to optimally deviate from the restrictive shape of VAR-based IRFs, whenever these are poorly supported by the data. This, while the discipline imposed by the prior, allows to retain reasonable estimation uncertainty at all horizons. Hence, BLP can sensibly reduce the impact of compounded biases over the horizons, effectively dealing with model misspecifications.

4.3.2 Impulse Response Functions

The main results of this section are that impulse response functions (IRFs) with two exogenous shocks differ along some important dimensions, using the VAR equation (11)\(^4\). Figure 4 to Figure 6 show exogenous offshore-relative-to-onshore bond demand shocks from different sources in the money market with the Bayesian local projection method. Figure 7 to Figure 9 display exogenous non-issuance-related use of currency forward contracts shocks from different sources in the currency market with the Bayesian local projection method.\(^5\)

\(^4\)The VAR appendix shows the link between the theoretical model and the empirical equation.
\(^5\)All IRFs have a 90% confidence interval. Variables pass the augmented Dickey-Fuller test and conclude a stationary process. Akaike’s information criterion (AIC), Schwarz’s Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC) lag order selection statistics provide an optimal

16
\[
\begin{bmatrix}
\omega & -D & D \\
2D & \frac{\tau}{\gamma} & 0 \\
-D & 0 & \frac{1}{\gamma}
\end{bmatrix}
\begin{bmatrix}
\mu_t \\
c_t \\
b_t
\end{bmatrix}
= B_0 + B_1 \begin{bmatrix}
\mu_{t-1} \\
c_{t-1} \\
b_{t-1}
\end{bmatrix} + B_2 \begin{bmatrix}
\mu_{t-2} \\
c_{t-2} \\
b_{t-2}
\end{bmatrix} + B_3 \begin{bmatrix}
\mu_{t-3} \\
c_{t-3} \\
b_{t-3}
\end{bmatrix} + B_4 \begin{bmatrix}
\mu_{t-4} \\
c_{t-4} \\
b_{t-4}
\end{bmatrix} - \begin{bmatrix}
0 \\
\varepsilon_{c,t} \\
\varepsilon_{b,t}
\end{bmatrix}
\] (11)

For money market shocks, Proposition 1 test, if \( \varepsilon_c \downarrow \), then \( c \uparrow \Rightarrow \mu \uparrow \Rightarrow b \uparrow \). In Figure 4, the changed reserve ratio would cause that simultaneous effect of a 1% increase in interest rate term spread differential (offshore-relative-to-onshore money market cost) will lead a 0.3% increase in the share of onshore bond issuance which would raise transaction cost by 0.85% (onshore-relative-to-offshore currency market cost). In Figure 5, the stock market substitution effect influences the term spread differential by a 1% raise; then, offshore money market cost raises 1.1% of onshore transaction cost following by onshore issuance share 0.16% jump. In Figure 6, the result of reverse repurchase agreement operations is consistent with model prediction. A 1% increase in \( c \) triggers around a 1% increase in \( b \) through the more onshore issuance \( \mu \) by 0.5%.

Figure 4: Monetary policy - changed reserve ratio \( \varepsilon_c \downarrow \)

lag number 4. Please see the IRFs appendix for more details with other methods - VARs and LPs.
Figure 5: Investor preference - stock market substitution effect $\varepsilon_c \downarrow$

Figure 6: Money market regulatory - reverse REPO of open market $\varepsilon_c \downarrow$

For currency market shocks, Proposition 1 test, if $\varepsilon_b \downarrow$, then $b \uparrow \Rightarrow \mu \downarrow \Rightarrow c \uparrow$. In Figure 7, CNY/CNH liquidity would cause that simultaneous effect of a 1% increase in transaction cost (onshore-relative-to-offshore currency market cost) will be a 2.5% decrease in the share of onshore bond issuance which would raise interest rate term spread differential by 1% (offshore-relative-to-onshore money market cost). In Figure 8, offshore-relative-to-onshore exchange rate volatility affects transaction costs by a 1% increase; then, onshore currency market cost raises 2% of offshore money market cost following by onshore issuance share 1.4% fall. In Figure 9, the result of capital control is consistent with model prediction. 1% increase in $b$ triggers around a 3% increase in $c$ through the less onshore issuance $\mu$ by 3.5%.
In shorts, one market shock can transmit to the other market through capital flows. The spot money market is more sensitive to shocks from the forward currency market through capital flows. The more significant capital flows under uncertainty shocks from the forward
currency market would cause that transaction cost is more volatile, due to exchange-rate overshooting. The effects decay in a week after initial shocks, but the effect on capital flows is less persistent.

4.4 Proposition 2 & 3 Tests

4.4.1 Long Run Propensity

The cumulative effect of a permanent change in $X_t$ on $Y_t$ will be the sum of the coefficients, known as the long run propensity (LRP). This paper uses the Koyck (geometric lag) model to provide evidence of Proposition 2 and 3. This model allows for feasible estimation of $Y_t = \beta_0 + \delta_0 X_t + \delta_1 X_{t-1} + \delta_2 X_{t-2} + \ldots + \delta_q X_{t-q} + \ldots + u_t$ under assumption that $\delta_i = \delta_0 \lambda^i$ where $0 < \lambda < 1$. Thus, the value of the impact multipliers ($\delta$) decreases geometrically as the associated lag (i) increases. A larger value of $\lambda$ (closer to 1) means a greater persistence of lagged values. The estimation equation is $Y_t = \beta_0 + \lambda Y_{t-1} + \delta_0 X_t + u_t$, so the long run propensity is $LRP = \frac{\delta_0}{1-\lambda}$. Therefore, this model shows not only simultaneous effect but also cumulative effect (LRP).

4.4.2 Regression

Koyck (geometric lag) model tests Proposition 2 & 3 to estimate long run propensity, also involving endogeneity, heteroskedasticity, and auto-correlated errors problems. Therefore, this paper uses two-stage least squares (2SLS) instrumental variables and robust standard errors method to solve these problems, also adds some control variables ($\Delta$RRR, HSI-CSI, R-REPO, BAS, DCPR, $\Delta$CCI) from money and currency markets into the estimation equation. For Proposition 2 with equation (12), the share $\mu$ and gap $c - b$ have endogenous problems, so the sixth lag of gap $c - b$ is the instrumental variable for current gap $c - b$. From Proposition 1 results, the sixth lag is deep enough for an instrumental variable. The Proposition 2 test $(c - b) \downarrow \Rightarrow \mu \downarrow$ estimates insignificant $\lambda_{p2} = 0.019$ which implies little persistence, and significant $\delta_{0,p2} = 0.305$ as model prediction. As a result, the simultaneous effect of a 1% decrease in offshore-relative-to-onshore bond issuance cost $c - b$ will be a 0.305% decrease in the share of onshore bond issuance. Therefore, cheaper net cost of issuance in offshore induces more issuance flow in offshore and less issuance in onshore.

$$\mu_t = \beta_{p2}^* + \lambda_{p2} \mu_{t-1} + \delta_{0,p2}(c - b)_t + B_{p2 \text{control variables}} + u_{p2,t}$$

$^6$see Koyck model derivation appendix for more details
\begin{equation}
|c - b|_t = \beta_{p3}^* + \lambda_{p3}|c - b|_{t-1} + \delta_{0,p3}\log(D_t) + B_{p3}\text{control variables}_t + u_{p3,t}^*
\end{equation}

For Proposition 3 with equation (13), the sum of onshore and offshore bond ETFs amount is the total debt issuance with logarithmic form. Also, there is an endogenous problem. This regression chooses the third lag of debt as its instrumental variable. The Proposition 3 test \( \frac{\partial |c-b|}{\partial D} < 0 \) provides significant \( \lambda_{p3} = 0.854 \) which implies high level of persistence, and significant \( \delta_{0,p3} = -0.03 \) as model prediction. The simultaneous effect of a 1\% increase in total bond issuance will be a 0.03 basis point decrease in the absolute gap of interest rate \( |c-b| \). However, the cumulative effect (LRP) of a 1\% increase in total bond issuance will be a 0.205 basis point decrease in the absolute gap of interest rate \( |c-b| \). In a word, a large amount of debt issuance may decrease the absolute value of the net deviation. With infinity capital flows, the two deviations become identical.

Table 3: Regression - 2SLS IV and Robust Method

<table>
<thead>
<tr>
<th>( \mu_{\text{share}} )</th>
<th>( (c-b) )</th>
<th>( \text{debt}_\text{amount} )</th>
<th>( \text{cons} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c-b)</td>
<td>0.305*</td>
<td>-0.030*</td>
<td>97.634***</td>
</tr>
<tr>
<td>(0.1696)</td>
<td>(0.0183)</td>
<td>(0.0293)</td>
<td>(2.9035)</td>
</tr>
<tr>
<td>L1.( \mu_{\text{share}} )</td>
<td>0.019</td>
<td>L1.</td>
<td>c-b</td>
</tr>
<tr>
<td>(0.0293)</td>
<td>(0.0325)</td>
<td>(0.3463)</td>
<td></td>
</tr>
<tr>
<td>control variables</td>
<td>control variables</td>
<td>cons</td>
<td>cons</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.854***</td>
<td>0.690**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0325)</td>
<td>(0.3463)</td>
</tr>
<tr>
<td>N</td>
<td>410</td>
<td>N</td>
<td>274</td>
</tr>
<tr>
<td>Root MSE</td>
<td>3.031</td>
<td>Root MSE</td>
<td>0.273</td>
</tr>
</tbody>
</table>

5 Conclusion

China has both RMB onshore and offshore markets. The onshore CNY market is relatively regulated and controlled, but the offshore CNH market is relatively marketized and liberalized. The offshore market is the experimental field of RMB internationalization. This asymmetric phenomenon would cause many questions that are worth probing into. This paper implements the idea of Liao [2016] to explain Chinese onshore and offshore financial markets and fill the gap of the term spread differential and CIP violation spillover effects. From the model’s results, there are three propositions under the financial institution - a bank’s strategy in RMB money and currency markets. This paper also uses a flexible econometric method of Miranda-Agrippino and Ricco [2017], which can sensibly reduce the impact of compounded biases over the horizons and effectively deal with model misspecifications, to test Proposition 1 with different source of shocks. Another econometric method is two-stage...
least squares (2SLS) instrumental variables and robust standard errors under Koyck (geometric lag) model to test Proposition 2 & 3 simultaneous effect and long run propensity.

The results are three-fold: First, Proposition 1 - spillover of deviations: one market shock can transmit to the other market through capital flows. The shocks from the forward currency market have a large impact on the spot money market through capital flows. Also, these shocks from the forward currency market would cause overreacted capital flows, which makes the transaction cost more volatile because of exchange-rate overshooting. The effects on both markets would die away in a week after initial shocks, but the effect on capital flows is less persistent. Second, Proposition 2 - issuance flow and net deviation: cheaper net cost of issuance in offshore induces more issuance flow in offshore and less issuance in onshore. The profit maximization behavior of financial institutions could cause bond issuance movement to lower costs. Third, Proposition 3 - arbitrage capital and aligned deviations: a massive amount of debt issuance may decrease the absolute value of the net deviation. With infinity capital flows, the two deviations become identical. The asymmetric phenomenon implies that RMB markets are less efficient, so there would be some arbitrage opportunities. However, strict regulations and high costs can turn a possible arbitrage situation into an unfavorable one that has no benefit to investors and traders.
References


Wenxin Du, Alexander Tepper, and Adrien Verdelhan. Deviations from Covered Interest Rate Parity. 2016.


Appendices

A  Daily Capital Control Index

The daily capital control index is calculated by the unweighted average index of the following related financial categories in order to reflect the sensitivity of capital control policy changing. For each following financial related category, the index is between 1 and 0 where 1 means totally controlled and 0 vice versa (4th Jan 2010 is a benchmark date). If there is a policy change from full control to semi-open, the index becomes 0.5 from 1. Also, the index would be unchanged if there is not a newly released policy. The novel capital control index of China on a daily basis from 2010 to 2018 is based on the public information provided from the SAFE website and PBoC annual policy reports.\footnote{Qing Ge calculates the daily capital control index.}
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ka</td>
<td>Overall restrictions index</td>
</tr>
<tr>
<td>kai</td>
<td>Overall inflow restrictions index</td>
</tr>
<tr>
<td>kao</td>
<td>Overall outflow restrictions index</td>
</tr>
<tr>
<td>eq</td>
<td>Average equity restrictions</td>
</tr>
<tr>
<td>eqi</td>
<td>Equity inflow restrictions</td>
</tr>
<tr>
<td>eqo</td>
<td>Equity outflow restrictions</td>
</tr>
<tr>
<td>eq_plbn</td>
<td>Purchase locally by nonresidents (equity)</td>
</tr>
<tr>
<td>eq_siln</td>
<td>Sale or issue locally by nonresidents (equity)</td>
</tr>
<tr>
<td>eq_pabr</td>
<td>Purchase abroad by residents (equity)</td>
</tr>
<tr>
<td>eq_siar</td>
<td>Sale or issue abroad by residents (equity)</td>
</tr>
<tr>
<td>bo</td>
<td>Average bond restrictions</td>
</tr>
<tr>
<td>boi</td>
<td>Bond inflow restrictions</td>
</tr>
<tr>
<td>boo</td>
<td>Bond outflow restrictions</td>
</tr>
<tr>
<td>bo_plbn</td>
<td>Purchase locally by nonresidents (bonds)</td>
</tr>
<tr>
<td>bo_siln</td>
<td>Sale or issue locally by nonresidents (bonds)</td>
</tr>
<tr>
<td>bo_pabr</td>
<td>Purchase abroad by residents (bonds)</td>
</tr>
<tr>
<td>bo_siar</td>
<td>Sale or issue abroad by residents (bonds)</td>
</tr>
<tr>
<td>mm</td>
<td>Average money market restrictions</td>
</tr>
<tr>
<td>mmi</td>
<td>Money market inflow restrictions</td>
</tr>
<tr>
<td>mmo</td>
<td>Money market outflow restrictions</td>
</tr>
<tr>
<td>mm_plbn</td>
<td>Purchase locally by nonresidents (money market instruments)</td>
</tr>
<tr>
<td>mm_siln</td>
<td>Sale or issue locally by nonresidents (money market instruments)</td>
</tr>
<tr>
<td>mm_pabr</td>
<td>Purchase abroad by residents (money market instruments)</td>
</tr>
<tr>
<td>mm_siar</td>
<td>Sale or issue abroad by residents (money market instruments)</td>
</tr>
<tr>
<td>ci</td>
<td>Average collective investments restrictions</td>
</tr>
<tr>
<td>ci_i</td>
<td>Collective investments inflow restrictions</td>
</tr>
<tr>
<td>ci_o</td>
<td>Collective investments outflow restrictions</td>
</tr>
<tr>
<td>ci_plbn</td>
<td>Purchase locally by nonresidents (collective investments)</td>
</tr>
<tr>
<td>ci_siln</td>
<td>Sale or issue locally by nonresidents (collective investments)</td>
</tr>
<tr>
<td>ci_pabr</td>
<td>Purchase abroad by residents (collective investments)</td>
</tr>
<tr>
<td>ci_siar</td>
<td>Sale or issue abroad by residents (collective investments)</td>
</tr>
<tr>
<td>de</td>
<td>Average derivatives restrictions</td>
</tr>
<tr>
<td>dei</td>
<td>Derivatives inflow restrictions</td>
</tr>
<tr>
<td>deo</td>
<td>Derivatives outflow restrictions</td>
</tr>
<tr>
<td>de_plbn</td>
<td>Purchase locally by nonresidents (derivatives)</td>
</tr>
<tr>
<td>de_siln</td>
<td>Sale or issue locally by nonresidents (derivatives)</td>
</tr>
<tr>
<td>de_pabr</td>
<td>Purchase abroad by residents (derivatives)</td>
</tr>
<tr>
<td>de_siar</td>
<td>Sale or issue abroad by residents (derivatives)</td>
</tr>
<tr>
<td>di</td>
<td>Average direct investment restrictions</td>
</tr>
<tr>
<td>dix</td>
<td>Direct investment inflow restrictions</td>
</tr>
<tr>
<td>dio</td>
<td>Direct investment outflow restrictions</td>
</tr>
<tr>
<td>re</td>
<td>Average real estate restrictions</td>
</tr>
<tr>
<td>rei</td>
<td>Real estate inflow restrictions</td>
</tr>
<tr>
<td>reo</td>
<td>Real estate outflow restrictions</td>
</tr>
<tr>
<td>re_pabr</td>
<td>Purchase abroad by residents (real estate)</td>
</tr>
<tr>
<td>re_plbn</td>
<td>Purchase locally by nonresidents (real estate)</td>
</tr>
<tr>
<td>re_silbn</td>
<td>Sale locally by nonresidents (real estate)</td>
</tr>
</tbody>
</table>
B VAR

From equilibrium conditions of the static model:

\[
\mu = \frac{(c - b)D}{\omega} + \theta \\
= V \tau ((1 - 2\mu)D - \varepsilon_c) \\
b = -\gamma^2((1 - \mu)D + \varepsilon_b)
\]

Then, static model with time subscript in matrix form:

\[
\begin{bmatrix}
\omega & -D & D \\
2D & \frac{\tau}{V} & 0 \\
-D & 0 & \frac{1}{\gamma^2}
\end{bmatrix}
\begin{bmatrix}
\mu_t \\
c_t \\
b_t
\end{bmatrix}
=
\begin{bmatrix}
\theta\omega \\
D \\
-D
\end{bmatrix}
-
\begin{bmatrix}
0 \\
\varepsilon_{c,t} \\
\varepsilon_{b,t}
\end{bmatrix}
\]

\[
\begin{bmatrix}
\omega & -D & D \\
2D & \frac{\tau}{V} & 0 \\
-D & 0 & \frac{1}{\gamma^2}
\end{bmatrix}
= M
\]

Due to \(\det(M) = \frac{\omega\tau + \gamma^2D^2 + 2VD^2}{V\gamma^2} > 0\) (in other words, \(M^{-1}\) is the inverse of matrix \(M\)), this system has solution.

Therefore, VAR with optimal lags:

\[
\begin{bmatrix}
\omega & -D & D \\
2D & \frac{\tau}{V} & 0 \\
-D & 0 & \frac{1}{\gamma^2}
\end{bmatrix}
\begin{bmatrix}
\mu_t \\
c_t \\
b_t
\end{bmatrix}
= B_0 + B_1
\begin{bmatrix}
\mu_{t-1} \\
c_{t-1} \\
b_{t-1}
\end{bmatrix}
+ B_2
\begin{bmatrix}
\mu_{t-2} \\
c_{t-2} \\
b_{t-2}
\end{bmatrix}
+ B_3
\begin{bmatrix}
\mu_{t-3} \\
c_{t-3} \\
b_{t-3}
\end{bmatrix}
+ B_4
\begin{bmatrix}
\mu_{t-4} \\
c_{t-4} \\
b_{t-4}
\end{bmatrix}
- \begin{bmatrix}
0 \\
\varepsilon_{c,t} \\
\varepsilon_{b,t}
\end{bmatrix}
\]

Reduced Form VAR:

\[
\begin{bmatrix}
\mu_t \\
c_t \\
b_t
\end{bmatrix}
= M^{-1}B_0 + M^{-1}B_1
\begin{bmatrix}
\mu_{t-1} \\
c_{t-1} \\
b_{t-1}
\end{bmatrix}
+ M^{-1}B_2
\begin{bmatrix}
\mu_{t-2} \\
c_{t-2} \\
b_{t-2}
\end{bmatrix}
+ M^{-1}B_3
\begin{bmatrix}
\mu_{t-3} \\
c_{t-3} \\
b_{t-3}
\end{bmatrix}
+ M^{-1}B_4
\begin{bmatrix}
\mu_{t-4} \\
c_{t-4} \\
b_{t-4}
\end{bmatrix}
- M^{-1}
\begin{bmatrix}
0 \\
\varepsilon_{c,t} \\
\varepsilon_{b,t}
\end{bmatrix}
\]
C IRFs

Figure 10: Monetary policy - changed reserve ratio $\varepsilon_c \downarrow$

Figure 11: Investor preference - stock market substitution effect $\varepsilon_c \downarrow$

Figure 12: Money market regulatory - reverse REPO of open market $\varepsilon_c \downarrow$
Figure 13: Central bank policy - liquidity of currency market $\varepsilon_b \downarrow$

Figure 14: Trader expectation - volatility of currency market $\varepsilon_b \downarrow$

Figure 15: Currency market regulatory - capital control $\varepsilon_b \downarrow$
D  Koyck Model Derivation

Substitute $\delta_i = \delta_0 \lambda^i$ into $Y_t = \beta_0 + \delta_0 X_t + \delta_1 X_{t-1} + \delta_2 X_{t-2} + \ldots + \delta_q X_{t-q} + \ldots + u_t$, and lag one period:

$Y_{t-1} = \beta_0 + \delta_0 X_{t-1} + \delta_0 \lambda X_{t-2} + \delta_0 \lambda^2 X_{t-3} + \ldots + \delta_0 \lambda^q X_{t-q-1} + \ldots + u_{t-1}$

then multiply both sides of above equation by $\lambda$:

$\lambda Y_{t-1} = \lambda \beta_0 + \delta_0 \lambda X_{t-1} + \delta_0 \lambda^2 X_{t-2} + \delta_0 \lambda^3 X_{t-3} + \ldots + \delta_0 \lambda^{q+1} X_{t-(q+1)} + \ldots + \lambda u_{t-1}$

then use original equation minus this new equation:

$Y_t - \lambda Y_{t-1} = (1 - \lambda) \beta_0 + \delta_0 X_t + u_t - \lambda u_{t-1}$

estimate the model:

$Y_t = \beta^* + \lambda Y_{t-1} + \delta_0 X_t + u^*_t$

where $\beta^* \equiv (1 - \lambda) \beta_0$ and $u^*_t \equiv u_t - \lambda u_{t-1}$.

Therefore,

$$LRP = \sum_{i=0}^{n} \frac{\partial Y_t}{\partial X_{t-i}} = \sum_{i=0}^{n} \delta_i = \sum_{i=0}^{n} \delta_0 \lambda^i = \frac{\delta_0}{1 - \lambda}$$